SYNOPSIS V2.0:
Heavy Ion Latch-up Test Results for the Altera Stratix FPGA EP1S25

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TEST DATE: March 14, 2005   REPORT DATE: April 8, 2005

I. INTRODUCTION

This second test was performed to determine the radiation-induced heavy ion Single Event Latchup (SEL) and Single Event Upset (SEU) sensitivities of the Altera Stratix EP1S25 Field Programmable Gate Array (FPGA). The testing was conducted at the Texas A&M Cyclotron Radiation Effects Facility in College Station, TX. The power supply current was monitored for large increases, and the devices were monitored for functionality with an oscilloscope throughout the irradiation process.

A laser test was attempted at the Naval Research Laboratory (NRL) in Washington, DC to test for sensitivities of the Altera FPGA. The metal of device was found to be to thick for the laser to penetrate. A second ion test of the FPGA was needed to verify latchup conditions.

II. DEVICES TESTED

The Altera Stratix EP1S25 is based on a 1.5V, 0.13-μm, all layer copper SRAM process, with a density up to 25,660 logic elements and up to 2 Mbits of RAM. This device offers up to 10 Digital Signal Processing (DSP) blocks with up to 80 (9-bit x 9-bit) embedded multipliers and up to 6 Phase-Locked Loops (PLLs). Two samples of the Device Under Test (DUT) were tested.

III. TEST FACILITY

Facility: Texas A&M Cyclotron Facility.
Flux Range: 1.59×10^4 to 1.74×10^4 particles/cm^2/s.
Particles: Neon was used.
Device Markings:
EP1525F672C6L
ADK9E0401A

Ion	Angle of Incidence	Energy (MeV)	LET (MeVcm^2/mg)	Range in Silicon (μm)
Ne	0	262	2.8	256

IV. TEST METHODS

Temperature: room temperature in air

Test Hardware: This test consisted of a DUT Board and a SEU Monitoring Board provided by Altera with a power cable for each. A serial cable was used to connect test hardware to a monitor PC and jumper wires for board interconnections. For monitoring current, a Digital Multi-Meter (DMM) was utilized. A relay was placed between the DUT Board and the SEU Monitoring Board for the ground jumper for user control of interconnection from outside the chamber. This also served as an error simulator. A switch was connected between the DMM and the DUT Board to break the circuit and disable power from the DUT Board, thus giving the flexibility of performing a power reset to the DUT Board upon latchup or loss of configuration.

Software: A HyperTerminal Program was utilized to connect to the serial ports of the PC. The configuration makeup was 115 kbps, 8 data bits, 1 stop bit, no parity, and no hardware handshaking.

Test Techniques: Tests were performed to screen for susceptibility to SEL and SEU and measure sensitivity as a function of Linear Energy Transfer (LET) for an application specific test setup. The test conditions included an AC power cable that converted the AC to 5V DC. This cable was connected to the DUT Board's voltage regulator, which released 3.3V to the DUT Board components. Two DUT's were exposed to radiation. They were programmed with a checkerboard or binary counting pattern. An equivalent normal-incidence fluence of at least 1×10^7 ions/cm^2 was used at each test condition unless an SEL occurred. A beam flux range of 1.59×10^4 to 1.74×10^4 particles/cm^2/s resulted in individual exposures between 8 seconds and 5 minutes and 43 seconds.

The input voltage condition was evaluated at 1 value of LET. Testing began a normal incident LET of 2.8 MeV-cm^2/mg obtained with Neon ions.
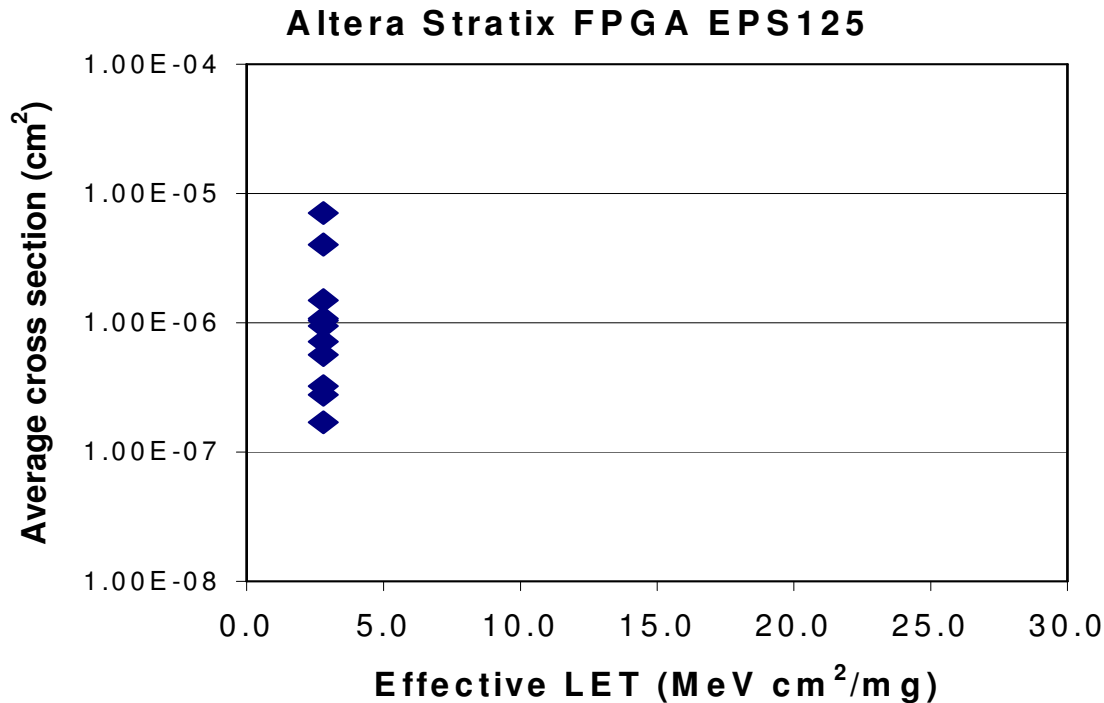
Device functionality was monitored on the PC via the HyperTerminal software and current was monitored on the DMM throughout irradiation. If the device current experienced a sudden increase larger than $I_{L\ =\ 350mA}$, or if the output of the devices ceased to correspond to the input, the power was cycled or reset and the DUT was checked for functionality; we saw high current but it may have been bus conflicts. In some cases, the power was not cycled immediately or reset, but a reconfiguration was required. The DUT functionality information was not saved to a file, but was recorded in the run log.

V. RESULTS

The devices were exposed from a fluence of 1.42 x 10^5 to 3.10 x 10^6 particles/cm^2 of the Neon.

The test conditions and results are summarized in Table 1. The table is organized in the order in which the test runs were conducted. A quick look at the results shows that latchup occurred for both devices during the dynamic testing. DUT's 1 and 2 were tested with the FPGA programmed with a binary counting pattern or checkerboard pattern.

Table 1. Test Conditions & Results
DUT #	Angle (Degrees)	Effective LET (MeV-cm^2/mg)	Latchup	Cross Section (cm^2)
1	0	2.8	1	5.65E-07
1	0	2.8	1	1.08E-06
1	0	2.8	1	2.77E-07
1	0	2.8	1	7.14E-07
1	0	2.8	1	1.70E-07
1	0	2.8	1	9.43E-07
2	0	2.8	1	1.49E-06
2	0	2.8	1	3.23E-07
2	0	2.8	1	1.04E-06
2	0	2.8	1	7.04E-06
2	0	2.8	1	4.02E-06

Altera Stratix FPGA EPS125

VI. COMMENTS AND RECOMMENDATIONS

In general, devices are categorized based on heavy ion test data into one of the four following categories:

Category 1 Recommended for usage in all NASA/GSFC spaceflight applications.

Category 2 Recommended for usage in NASA/GSFC spaceflight applications, but may require mitigation techniques.

Category 3 Recommended for usage in some NASA/GSFC spaceflight applications but requires extensive mitigation techniques or hard failure recovery mode.

Category 4 Not recommended for usage in any NASA/GSFC spaceflight applications.

This FPGA is susceptible to latchup due to the fact that it needed a power reset each time a rise in current occurred for the device to properly function again. It should be noted that after the power reset the device did perform correctly.

In general, the Radiation Effects and Analysis (REA) group does not recommend the use of devices in space flight applications that experience an SEL at an LET less than or equal to 37 MeV-cm[2]/mg. Because Altera Stratix EP1S25 experienced SEL well below 37 MeV-cm[2]/mg, this device is not considered a suitable spaceflight candidate. (Category 4)